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AN INTRODUCTION TO
ADVANCED ELECTRONIC CONCEPTS IN LAUNCH OPERATIONS

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by

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FUTURE STUDIES BRANCH

LAUNCH SUPPORT EQUIPMENT ENGINEERING DIVISION

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ABSTRACT

This report presents several concepts utilizing advanced electronic techniques and devices which would reduce the number of hard-wire umbilical connections to a space vehicle during pre-launch, ground-launch, and orbital-launch operations. Included is a discussion of advanced devices applicable to present and future implementations of the concepts. The major emphasis has been placed on the implementation of light beams as information carriers to replace hard wire presently being used as the interconnecting medium.

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DEFINITION OF SYMBOLS

SYMBOL	DEFINITION
Ga	Galium
As	Arsinide
RF	Radio Frequency
FM	Frequency Modulation

UNUSUAL TERMS

LASER	Light Amplification by Simulated Emission Radiation
LUT	Launcher Umbilical Tower
OLF	Orbital Launch Facility

SECTION I

INTRODUCTION

A. PURPOSE

The purpose of this document is to present several advanced electronic concepts which would significantly reduce the number of hardline connections required to check-out and launch a space vehicle.

It is expected that ramifications of these concepts will soon be in the hardware stages of development, and many problems that have been associated with umbilicals, swing arms, and their relatives will be eliminated. The technology of advanced devices will be a definite asset in many of these concepts, but it is emphasized that the state-of-the-art today can be used for all concepts presented.

B. SCOPE

Section II of this report describes present techniques of hardline connections, considers alternate solutions, and details the recommended solution for ground-launch and orbital-launch operations.

In the ground-launch operations portion of Section II, several specific interfaces are chosen to show how the recommended concept could be implemented. The advantages to be gained and the problems involved are discussed. Sketches are included to show the concept as it would be implemented for the specific interface.

In the orbital-launch operations portion of Section II, the problems of hard-wire connections in this environment are discussed with the solution recommended for the ground-launch operation shown to be adaptable to orbit launch operations and having several unique advantages. Sketches are included to show the concepts as implemented in the orbital-launch operations environment.

SECTION II

ANALYSIS

A. GROUND LAUNCH OPERATIONS

Within the time span beginning with the first experiments with rockets and the forthcoming launch of the SA-7, tremendous progress has been made in all technical areas of rocketry. New materials have been developed for stronger and lighter structures, better insulating properties, and better sealants. Propellants are being developed which utilize hydrogen, fluorine, and combinations of fluorine-oxygen (FLOX). In electronics, technology has produced smaller and more accurate equipment almost continually since the vacuum tube. New microminiature devices discovered in laboratories three years ago are being utilized in so many various ways that producers of these devices are still behind in filling orders. In only one area has there been so little improvement as to be considered insignificant: the general family of devices called umbilicals. Even before Peenemunde when von Braun, Rudolf Nebel, and Klaus Riedel launched "MIRAK I", ignition was accomplished by basically closing a switch in hardlines that connected the rocket to the power source. When SA-7 is launched, ignition will be accomplished by the same basic principle.

Since the desired objective is to reduce the number of hardline connections to a space vehicle, other techniques must be considered to perform the same functions. Reductions of hard wire for data transfer and low-power control functions would be the easiest to accomplish and constitute the main theme of this document. The techniques considered fall basically into one or more of the following: radio frequency, test equipment/vehicle system integration, and electro-optical techniques.

Of the three techniques listed, the optical technique appears to be the best suited for reliability, simplicity, and performance. Radio frequency and test equipment/vehicle system integration techniques are accompanied by many problems and create the adverse conditions shown in Appendix A which is a summary comparison of the three techniques.

1. Radio frequency:

The use of radio frequency links for various parameters now transmitted by hardlines would generate the following problems:

a. More RF frequencies would be added, causing interference between all the areas involved with the launch. This would become intolerable during a multiple launch when two vehicles were being prepared for launch in quick succession.

b. More RF noise would be added into an environment already burdened with it. Multiple launches again would be inhibited.

c. The probability of accidental ignition of pyrotechnics would be increased. During the investigation of the recent accident at the Cape, "outside radio noise" was one of the suspect areas.

d. Use of special equipment such as antenna "hats" to reduce spurious radiation would be required.

e. Static weight of the vehicle would be increased due to additional equipment and associated power and cooling requirements.

2. Test equipment integration:

Integration of test equipment with vehicle systems would generate the following problems:

a. The static weight of the vehicle would be increased due to added equipment and associated support equipment weights.

b. In order to maintain "on-board" equipment within reasonable volume and weight limitations, performance capability and capacity would be degraded. This would reduce confidence levels now attainable with ground equipment.

c. Data would have to be transmitted to the ground equipment by some means if records of parameters are to be kept. If data is not transmitted, fault isolation becomes difficult and failure analysis impossible.

d. During multiple launch operations when time is critical, the computing "power" of the ground based equipment for rapid fault isolation and repair is lost.

e. Changes in test equipment limits caused by vehicle modifications would be more difficult to make due to accessibility handicaps of working within the vehicle.

3. Optical:

The optical technique appears to be the best candidate to attain the goal of reducing hardline connections; therefore, this technique will be subjected to a more detailed discussion.

The optical technique involves the utilization of pulsed and/or modulated light beams for transmitting data and communications signals. Since power cannot as yet be transmitted by light beams, internal vehicle power must be used in some applications.

a. Pulsed light beams: This category includes those devices that are basically on-off in nature, i.e., photo diodes and light actuated silicon controlled rectifiers. The first devices to be used in the pulsed light beam concept are the silicon photo diode light sensor and a minature light bulb. Data would be used to turn the light bulb on and off in a digital manner or the simple presence or absence of light would be used. Extensions of the concept use fiber-optics bundles to avoid any possibility of signal degradation by fogging of interface or attenuation of the light path by vapor or blown dirt from the engine blast. Fused quartz fiber has a transmission efficiency quite adequate for the concepts in which fiber optics are shown. A general concept is shown in figure 1 of the types of signals that would be transmitted across an interface between general areas A and B. By using small light sources, such as the GE NE-77[1], and sensors, such as the TI LSX 600[2], a large number of light "circuits" could be contained within a small matrix arrangement. By having both sources and sensors on the interface matrix, commands could be sent as well as data received. It is possible that by using a fast enough light source, PCM data could be transmitted.

In method (a.) an event in area A closes relay contracts applying current to the control lead of the light source. In area B, a photo diode senses the illumination of the light source and generates an "event" voltage. This voltage in area B, representing an event in area A, was generated without physical connection to area A.

In method (b.) an analog signal in area A is converted to a digital representation of its magnitude by the A/D converter. By proper sequencing of on and off status of the light from the generation of the "mark signal," a Pulse Code

---

[1] GE NE-77. Low current, third wire controlled glow lamp, 0.275 inches diameter and 1.16 inches deep.

[2] TI LSX 600 N-P-N planar silicon light sensor, 0.92 inches diameter and 0.093 inches deep.

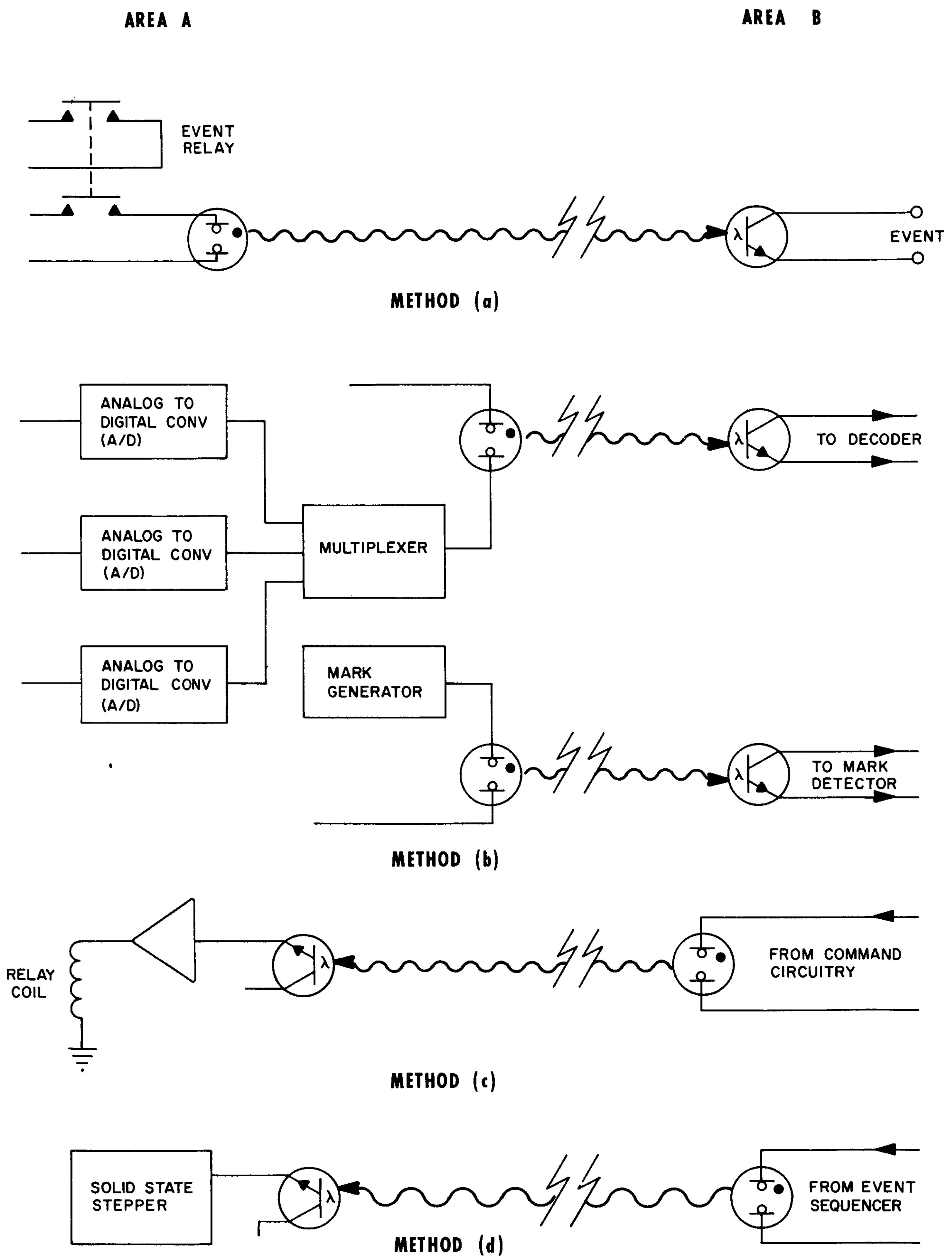


FIGURE 1. BASIC TECHNIQUES OF TRANSMISSION

Modulation (PCM) signal is transmitted across the interface by light. This PCM signal is the same type routinely sent by RF techniques in telemetry.

In method (c.) a command is generated in area B to illuminate the light source. The light sensor in area A detects the illumination and generates a voltage that can then be used to initiate the function desired by the command.

Method (d.) is a ramification of method (c.) showing a sequence generator in area B controlling a solid state stepper in area A. The solid state stepper in area A would duplicate the steps of the area B sequence generator.

Another device that could be used is the light actuated silicon-controlled rectifier (LASCR). (See figure 2.) When properly heatsinked, this light-actuated solid state switch can directly control up to 1.6 amps of DC current at 200 volts. Although the maximum frequency response of such devices is limited to around 1 KC, the device could be used in control circuits which do not have the higher frequency requirements of the data transmission circuits.

(1) Space vehicle and LUT interface: The implementation of the fiber optic bundle concept of figure 3, although not eliminating the connection completely, drastically reduces the complexity of it. This concept embodies exactly the same principles discussed for figures 1 and 2. The only difference is that the separation between the two areas (now the vehicle and LUT) is greater and is in an environment that could degrade the interface performance. A fiber optic bundle is used to bridge the gap between the vehicle and LUT. A fiber optic bundle is used for several reasons:

(a) The vehicle and LUT will be moving with respect to each other due to wind loads. For proper operation the corresponding lights and sensors in the matrix must be maintained at an exact index. The fiber optic bundle is used as a "flexible light path" to accomplish this requirement.

(b) Atmospheric environmental conditions could exist which would attenuate or completely destroy the light path. Propellant vapors drifting around the vehicle during loading could fog the face of the source/sensor matrices. Just before lift-off engine blast could blow dirt or other debris in between the matrices.

(c) Extraneous light sources could energize the sensors in an undesirable manner destroying data or causing functions to occur out of sequence. By providing an opaque cover over the fiber optic bundle and matrices, this probability is eliminated.

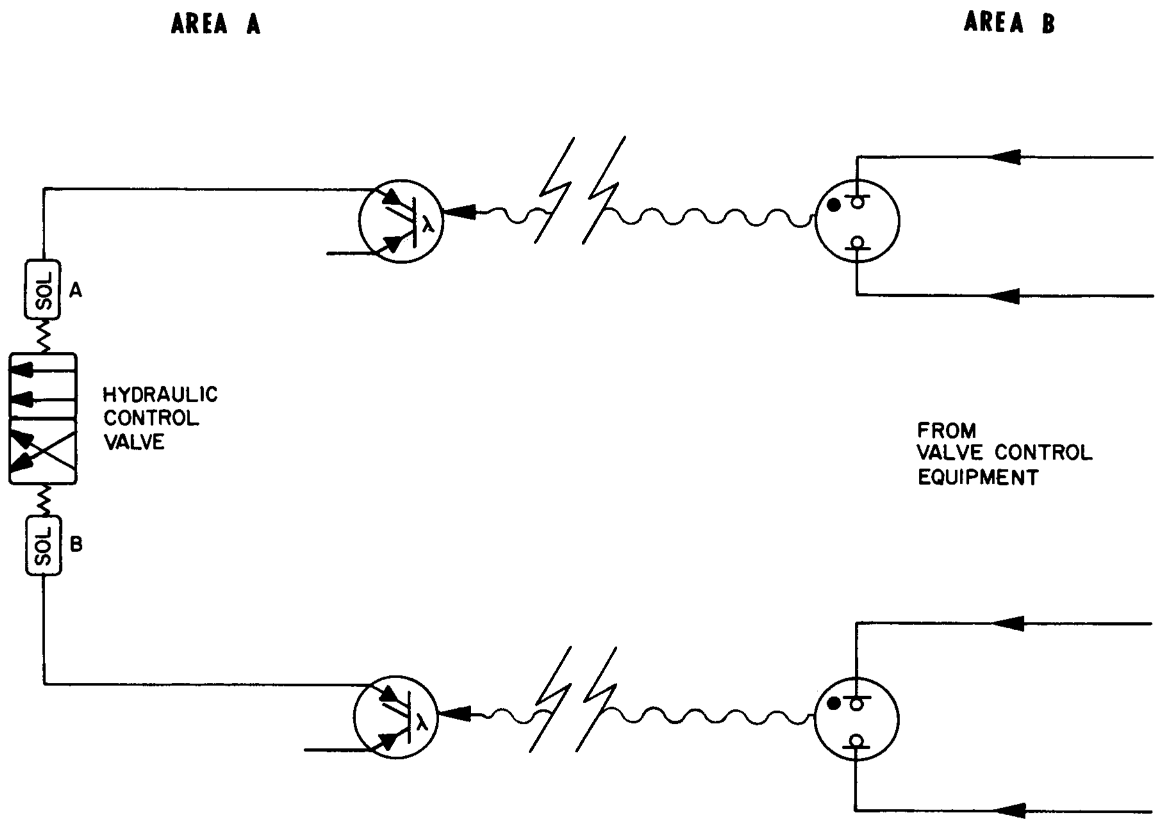


FIGURE 2. LASCAR IMPLEMENTATION

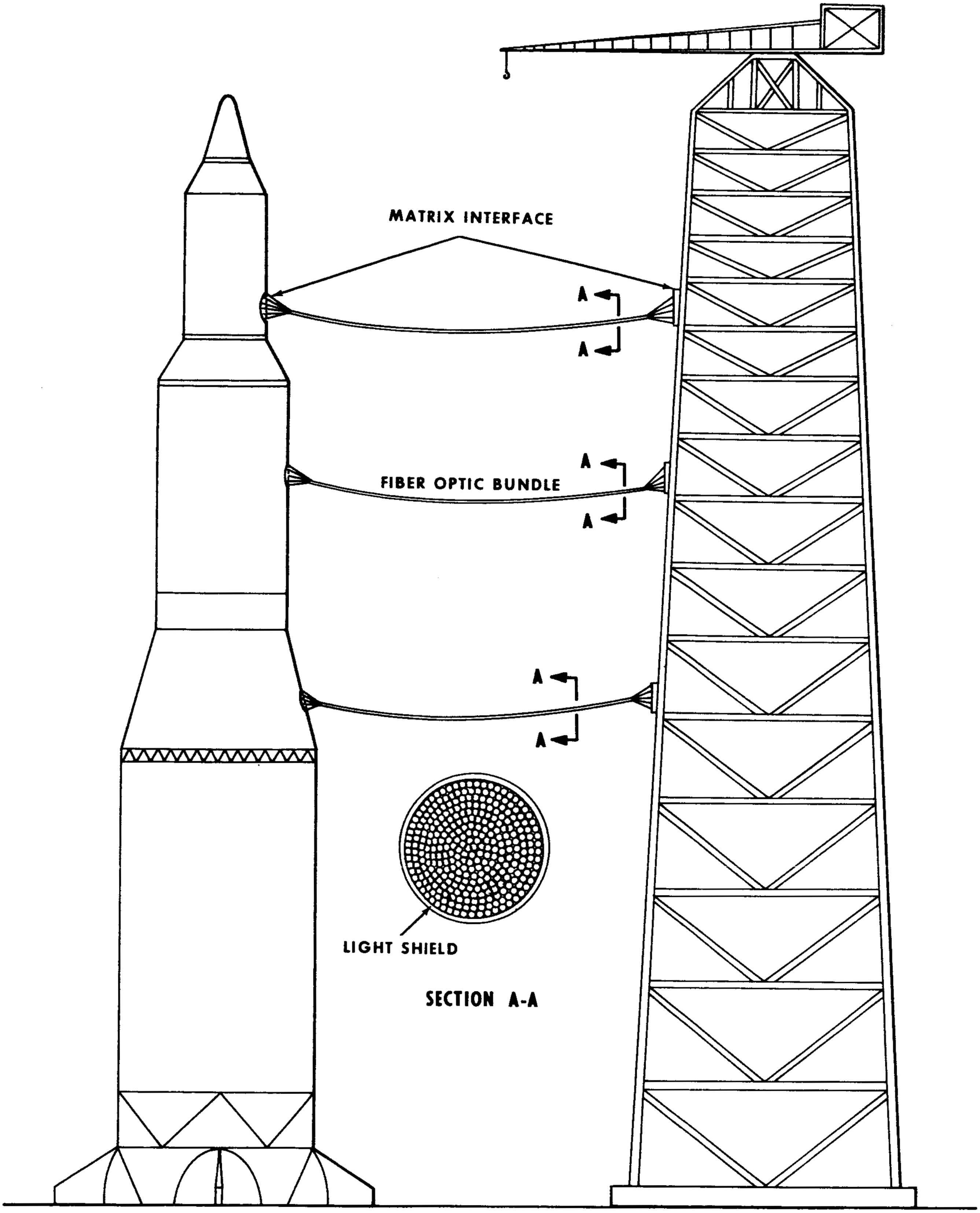


FIGURE 3. DATA TRANSMISSION BETWEEN LUT AND VEHICLE

The first implementation of this concept into a practical example shows the following advantages:

(a) Data transmission would neither generate nor be affected by RF noise or interference.

(b) The data would not have to be modulated or demodulated on an FM carrier saving the weight of modulation and demodulation equipment on the vehicle and its associated power and cooling requirements. There is the possibility that present encoder outputs could drive the light sources directly, but more probably a single stage voltage amplifier would be required.

(c) The small size of the light sources and sensors would allow, within a reasonably sized matrix assembly, many individual parameter transmissions for critical circuits.

(d) Conventional pin-socket connector problems, such as bent pins or punched-out sockets are eliminated.

(e) Disconnection at lift-off is made more simple and trouble-free because many complex electrical and mechanical connections have been eliminated.

Since data transmission by this technique is bi-directional, many operations could be commanded from outside the vehicle. A portion of the matrix assembly could consist of a sub-matrix of light sources controlled by a command sequencer or piece of automatic test equipment. The vehicle could interpret the command matrix by means of micro-miniaturized logic circuits which would add very little weight, volume, or power requirements to the vehicle.

(2) LUT and launch pad interface: Figure 4 shows how connect and disconnect time could be reduced at the launch pad and the LUT interface. This concept again utilizes on-off light source and sensing devices in a matrix configuration. By implementing this concept, the establishment of large data links between the LUT and launch pad is reduced to the following simple steps:

(a) The LUT is properly stationed at the launch pad by the crawler transporter, lowered onto the pad, and all mechanical supports attached.

(b) The launch pad's floating matrix is extended and positioned to the proper index location on the LUT matrix by self-alligning index keys. The simple light shield would be an integral part of the floating matrix.

(c) Power is applied and operation initiated.

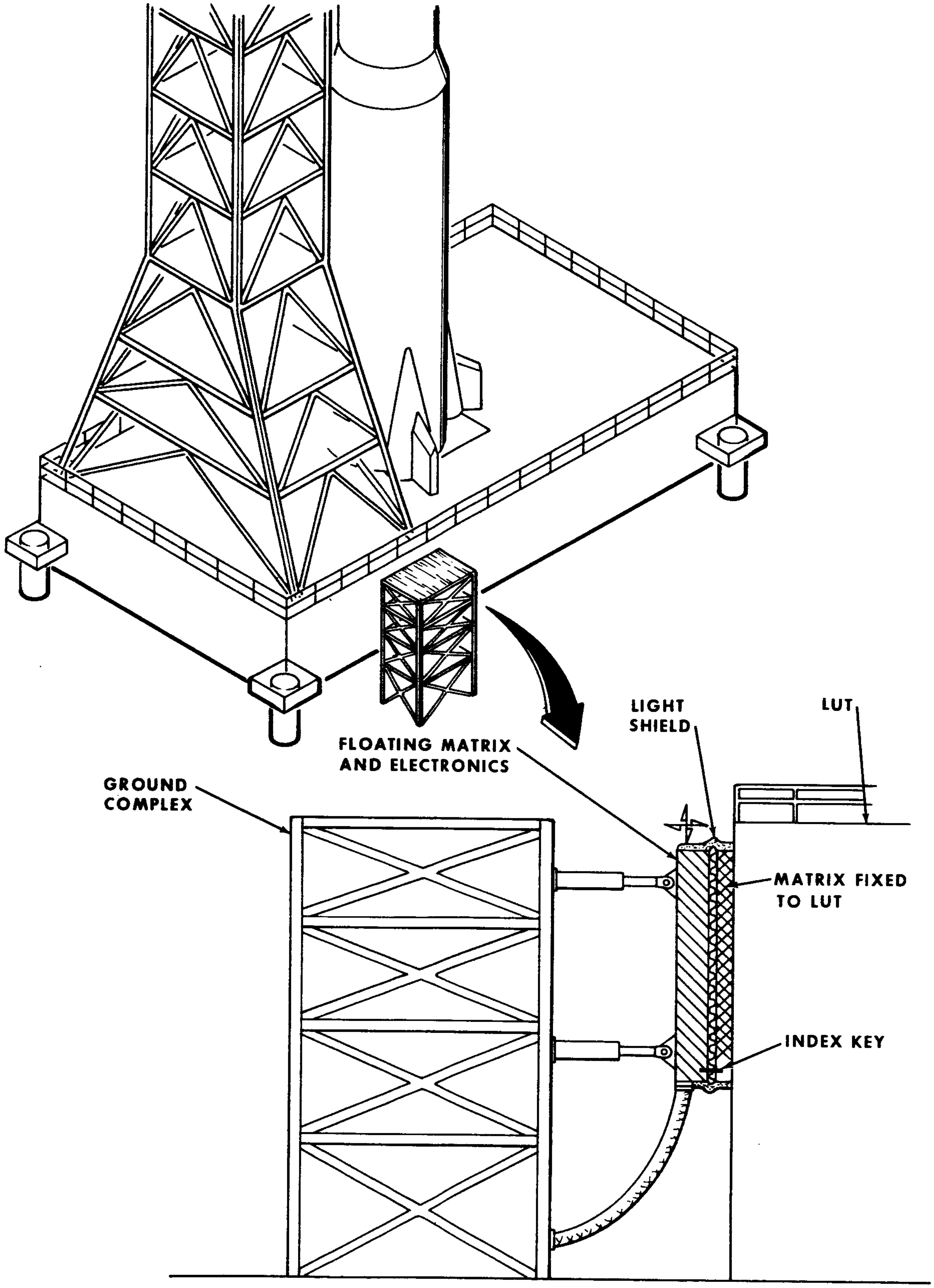


FIGURE 4. DATA TRANSMISSION BETWEEN LUT AND LAUNCH PAD

To disconnect the link for any reason at any time, the floating matrix is merely retracted away from the LUT matrix.

b. Modulated light beams: This category consists of various laser devices in different modes of operation. Of all the advanced optical communication devices, the laser is receiving the most attention. A tremendous amount of development work has been and is being done with lasers in all areas of communication including television picture transmission. Prototype military rangefinders are being evaluated. Studies are being conducted on the use of lasers in space communications and space tracking and rendezvous. Laser beams have been bounced off the moon, but still, hard wires are used for data transmission and simple control functions.

Some of the general features of lasers that will be used in developing the concepts that follow are:

High frequency of operation (5×10^{14} CPS) allows many different channels on a single beam. (5000 data channels with one light emitting diode)

Coherent beam of light allows secure communication and eliminates interference.

Present availability - many lasers and detectors are available commercially together with associated modulation devices.

Simplicity - injection lasers need only to be aimed at a detector and supplied with modulated current at low power levels. (3×10^{-5} watts)

The possibility of utilization in wireless power transmission techniques is being developed by at least one company today.

(1) Interlevel LUT Data Transmission: This concept, figure 5, would reduce the wiring for data and communications presently required on the LUT. Nearly all data and communications could be handled by two laser beams at each level of the LUT.

It is anticipated that during lift-off much of the wiring in the LUT will be damaged by heat, vibration, and pressure. The refurbishment costs after each launching could be reduced to re-checking black-box laser units instead of replacing cable trays, cables, connectors, and other associated wiring hardware that may be damaged. The laser black-boxes would be installed in heavily protected installations and the beams would be projected through the inside of equally heavy pipe. This installation

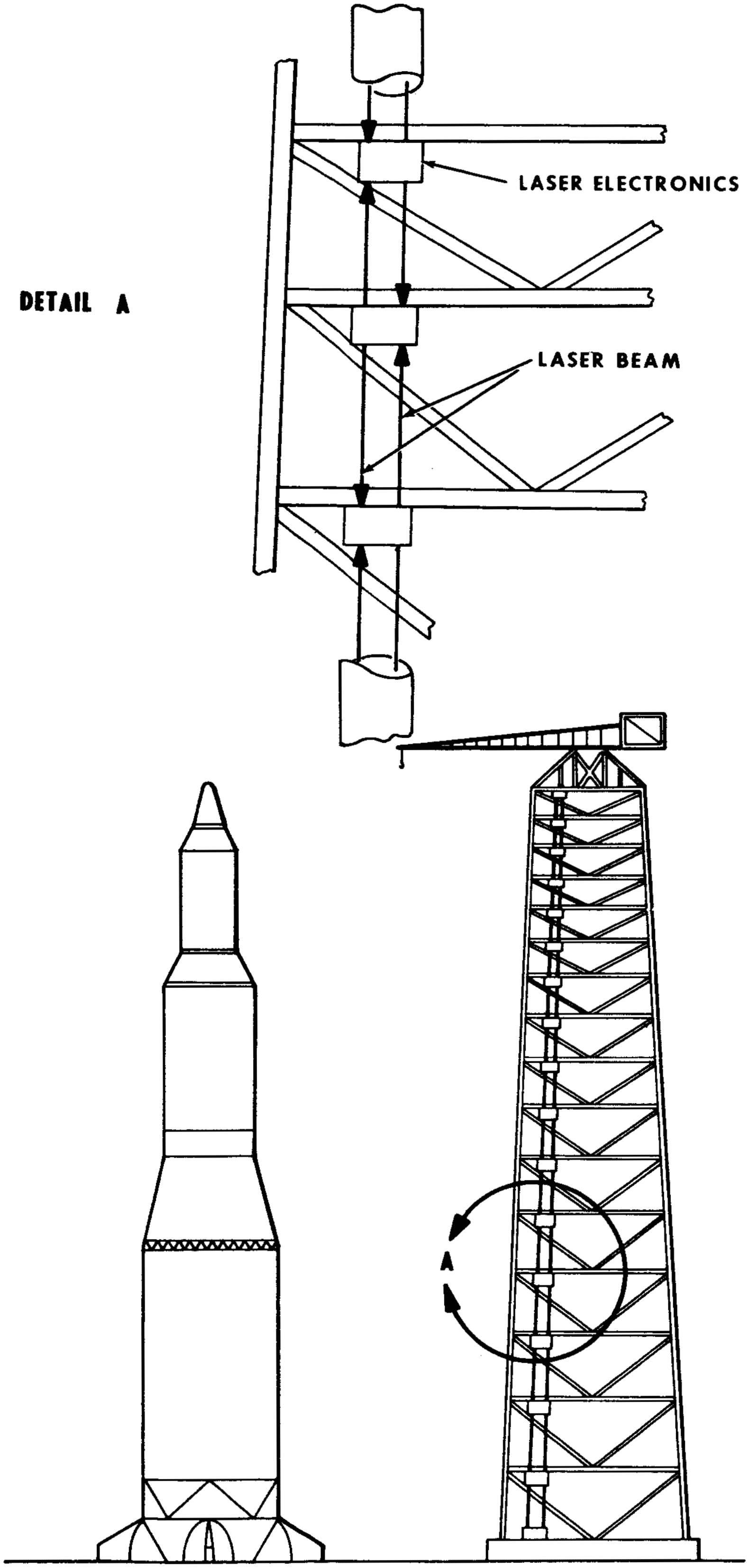


FIGURE 5. LEVEL TO LEVEL LUT TRANSMISSION

requirement serves two purposes. The first is to eliminate any possibility of foreign matter, such as vapors or dirt, attenuating the laser beam. Any fogging of the optical assembly could be easily prevented. Secondly, this type of installation would withstand the lift-off environment, and the laser units would not have to be replaced or repaired after each launching.

(2) LUT to launch pad: The use of a laser beam to establish a data link between the LUT and launch pad is depicted by the concept of figure 6. This concept is similar to the pulsed beam concept of figure 4 except that aiming of the laser beam eliminates extension and retraction of a matrix assembly.

(3) Vehicle to LUT: The next concept is the most complicated from an installation standpoint but offers one solution to many perplexing earth launch problems. The use of laser beams for data transmission between the LUT and the vehicle is shown in figure 7. It should be noted, however, that this concept does not eliminate the need for those connections which supply basic operating power, hydraulics, and pneumatics to the vehicle. One problem in this concept that was not present before is that the detector will be moving with respect to the laser source. This is caused by wind deflections of both the vehicle and the LUT. Figure 8 shows one simple method that might be used to keep the laser beam pointing at the detector on the vehicle. A target source of light, such as a gallium arsenide (GaAs) laser emitting a diffused beam of light, is mounted on the vehicle. A laser beam device, mechanically slaved to a tracking device, is mounted on the LUT so that both are pointing in a common direction. The tracker is manually pointed in the general direction of the target light source located on the vehicle. It will be assumed for purposes of explanation that the tracker has been pointed below the target but is not in error to the right or left. A disk, with a rounded pie section slot cut from it, and mounted in front of the detector in the tracker unit, is rotating at a constant speed about the axial centerline of the tracker. When the slot in the disk allows the target image to be received by the detector, the detector will generate a square wave pulse whose leading edge is caused by first "sight" of the target and trailing edge is caused by the disk rotating enough to block the image. This square wave pulse has two important characteristics:

The width of the pulse is controlled by the shape of the pie-section slot in the disk. The further away the target is from the axial centerline of the tracker, the wider the pulse will be.

The presence of the pulse can be correlated to the angular position of the slotted disk by a phase comparison operation.

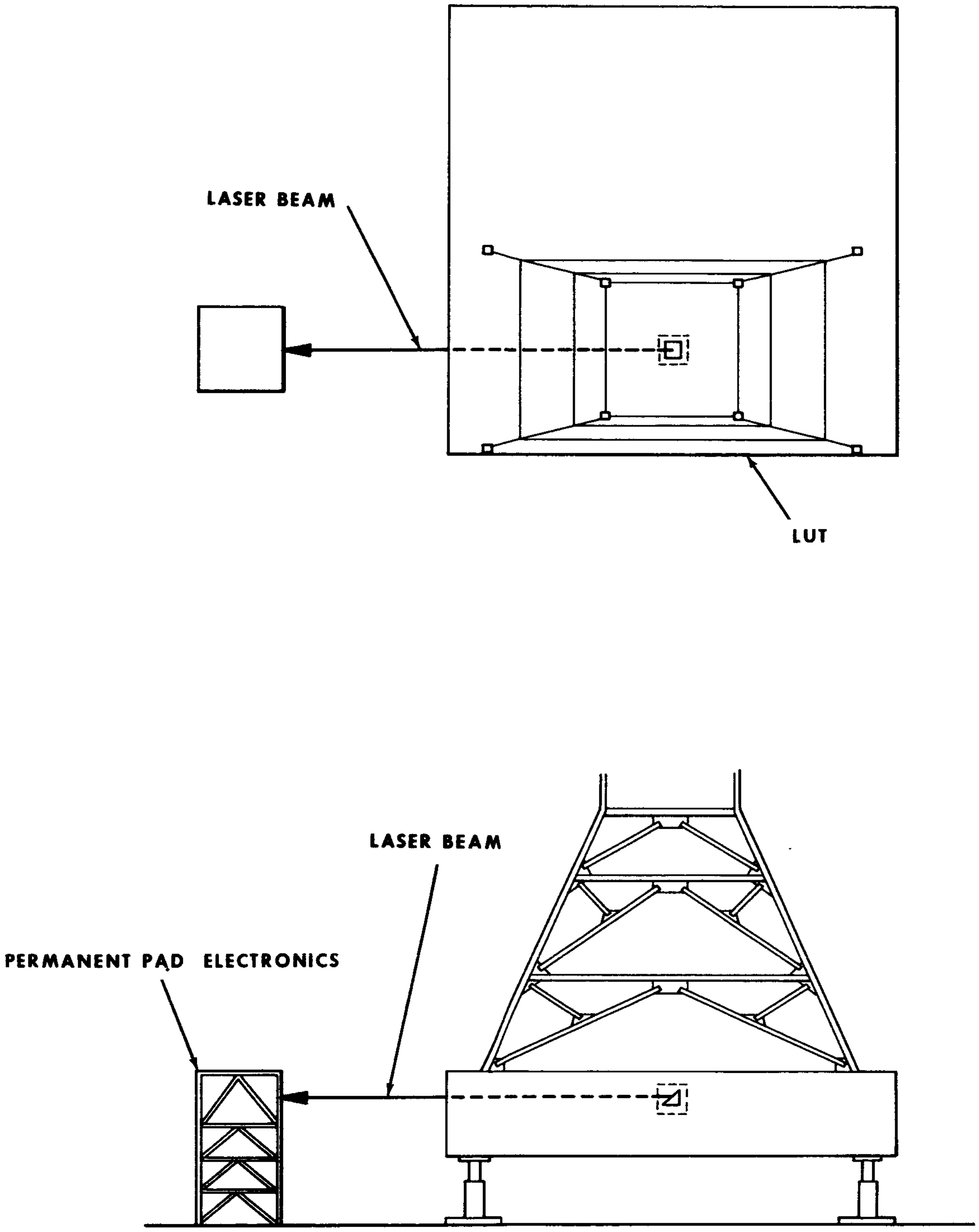


FIGURE 6. LASER LINK BETWEEN LUT AND LAUNCH PAD

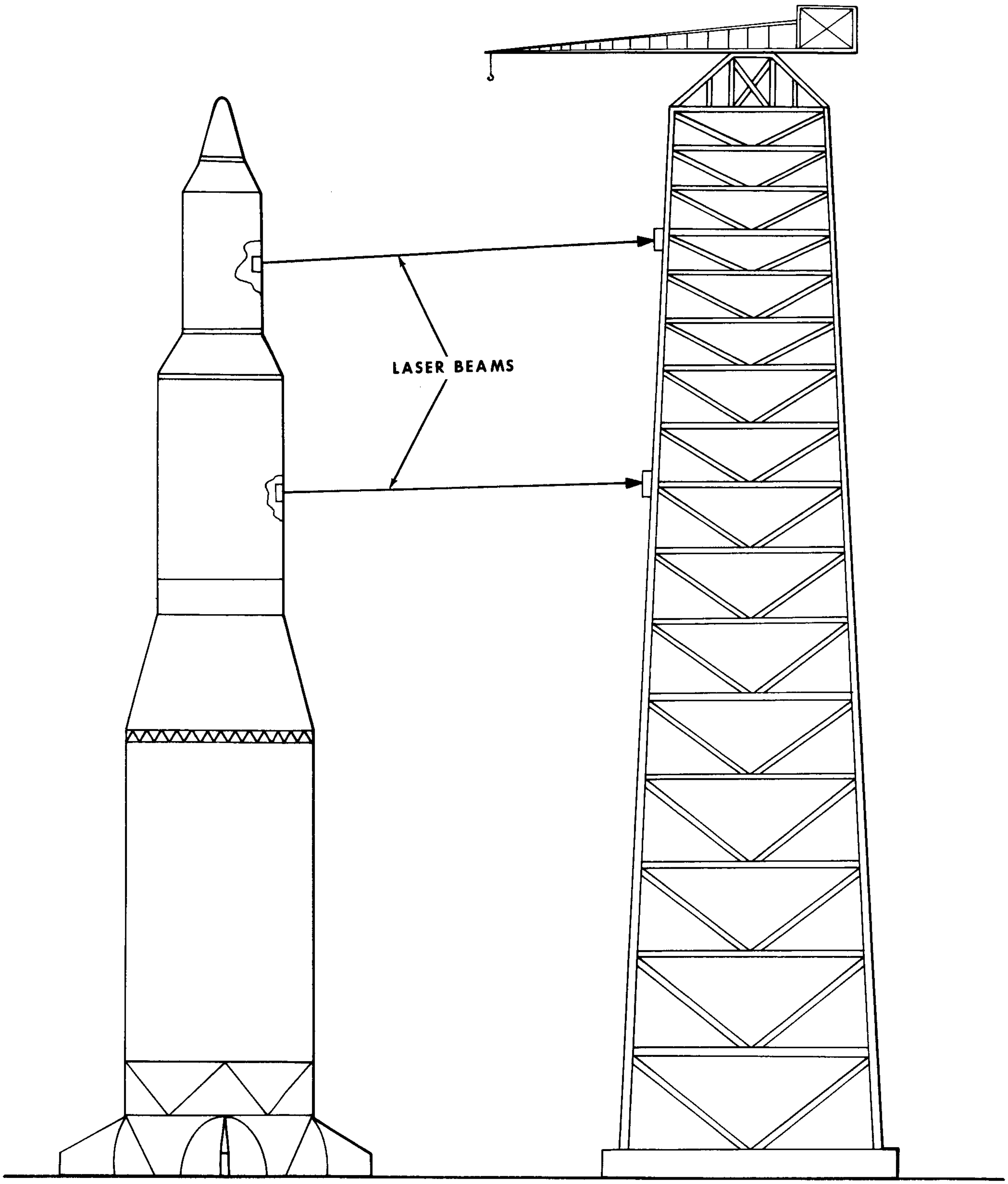
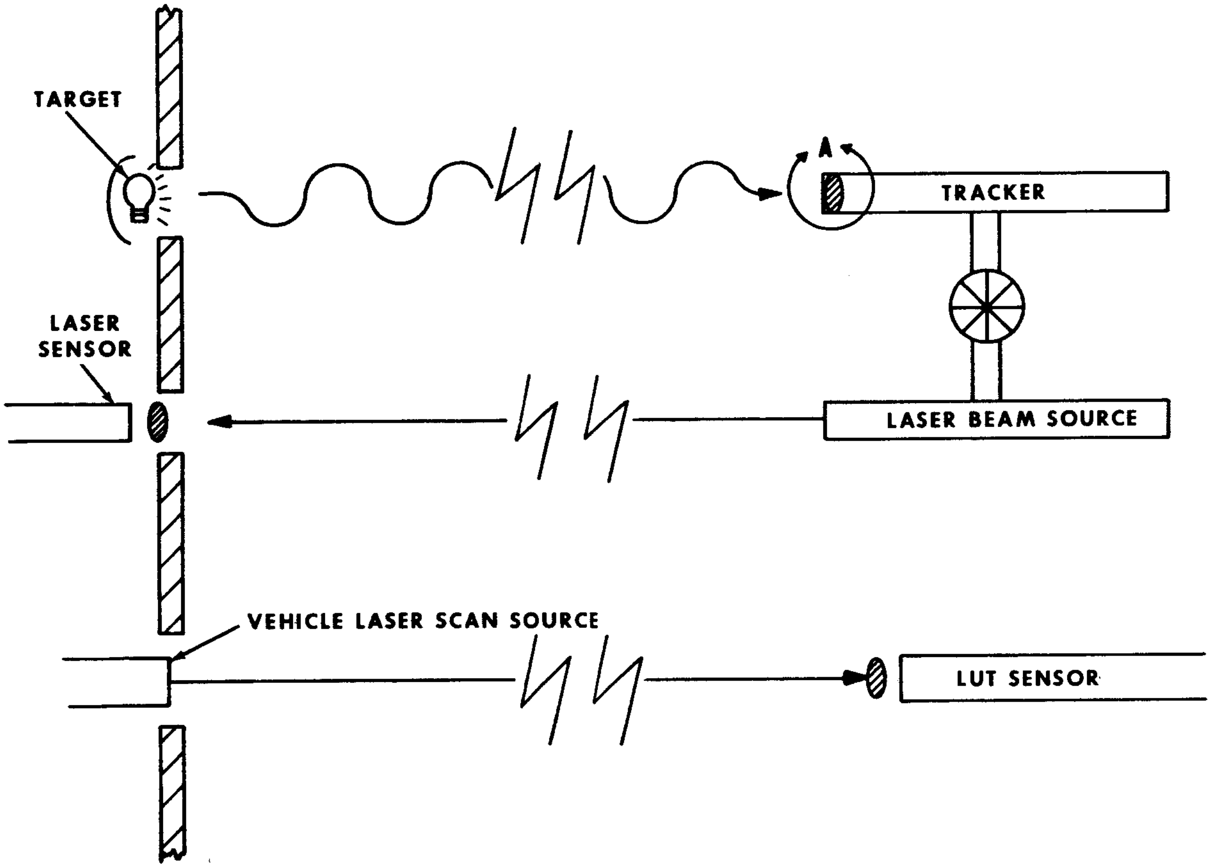
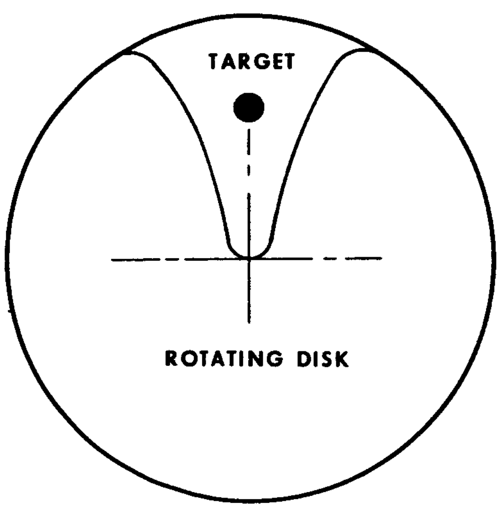


FIGURE 7. LASER LINK BETWEEN LUT AND VEHICLE





DETAIL A

FIGURE 8. CONCEPTUAL TRACKING TECHNIQUE

Figure 9 is a block diagram of how these two characteristics are used to correct the pointing error. The width of the pulse is integrated and smoothed to form a relatively constant bias magnitude to four transistors. The level of this bias is dependent on the amount of tracking error as developed previously. The direction of the error is determined by four "AND" logic gates. One input to each gate is supplied from the disk and the other input to each gate is received from the detector. Priminary information indicates that at the highest elevation on the LUT at which a data link would probably be established, a maximum sway would be $\pm$ 3 feet at right angles to the beam, vertical displacements caused by sway parallel to the beam and contraction/expansion might be one foot maximum and rotational movement negligible. The angles subtended by this sway could be compensated for optically, allowing fixed mounting of the data link both to the LUT and vehicle, but the possibilities opened up by having this type of system implemented warrant its use. Precautions would have to be taken to avoid attenuation of the line of sight. Suggested techniques would be compressed air jets and optical lens heaters. By making the aiming device accurate enough, and moving one of the data sources far enough away so that engine blast effects would not attenuate the necessary line of sight, communication could be maintained for a limited amount of time after launch. Back-up vehicle position data could thus be obtained which would not be affected by the ionized exhaust plume.

An actual system under development by Marshall Spaceflight Center (Reference 1) could be slightly modified for two-way communication use and to emphasize the advanced stage of development and availability of hardware techniques. Figure 10 shows in detail how this system might be used. In place of a light source on the vehicle, a corner reflector is used and light from a GaAs laser in the tracker is bounced off this reflector. Light from the laser is fed through a fiber optic and directed out through a 2.5-inch outside diameter 4-inch focal length projection lens. Beamwidth would be 0.5 degrees. This laser energy strikes the corner reflector array on the vehicle, is reflected back to the tracker, and is picked up by the reflective optics of a 6-inch telescope. Light collected by the primary mirror of the telescope is reflected back against a secondary mirror which bends it 90 degrees then through a passband filter into an image dissector. Electronics associated with the image dissector then generates error signals to point the LUT communication link more accurately at the vehicle sensor. If a partially silvered mirror were placed in the vehicle sensor optics, the communication link from the vehicle could be aimed by utilizing the LUT link beam as a target. The partially silvered mirror would allow 5 percent of the LUT beam to be passed onto an image dissector and electronics, while 95 percent would be reflected 90 degrees into interpreting equipment. Since the sensor on the LUT could provide a larger target for the vehicle's beam, the pointing accuracy of the vehicle electronics could be lower and would result in lighter and smaller packages requiring less power and cooling.

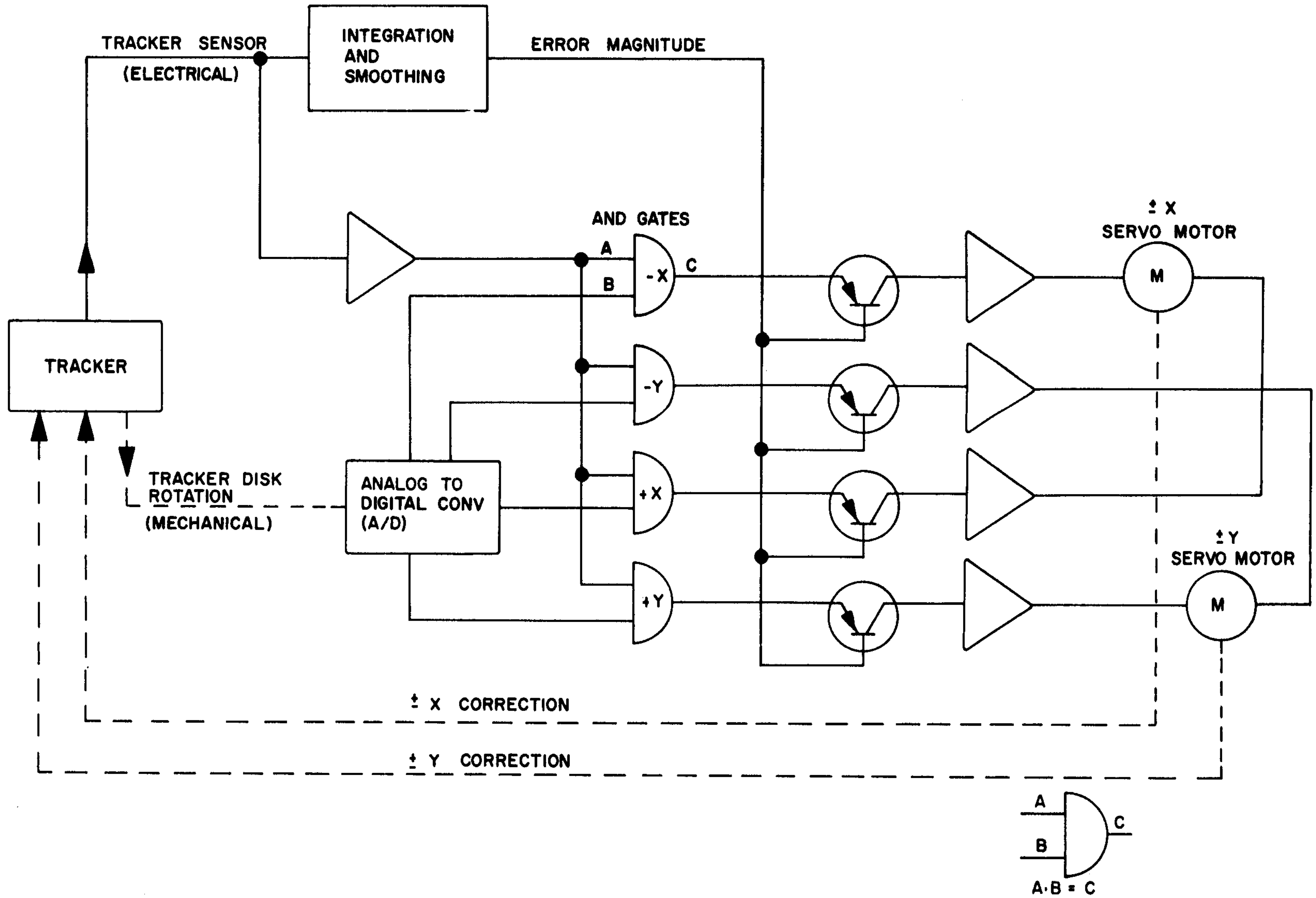


FIGURE 9. BLOCK DIAGRAM OF TRACKING ELECTRONICS

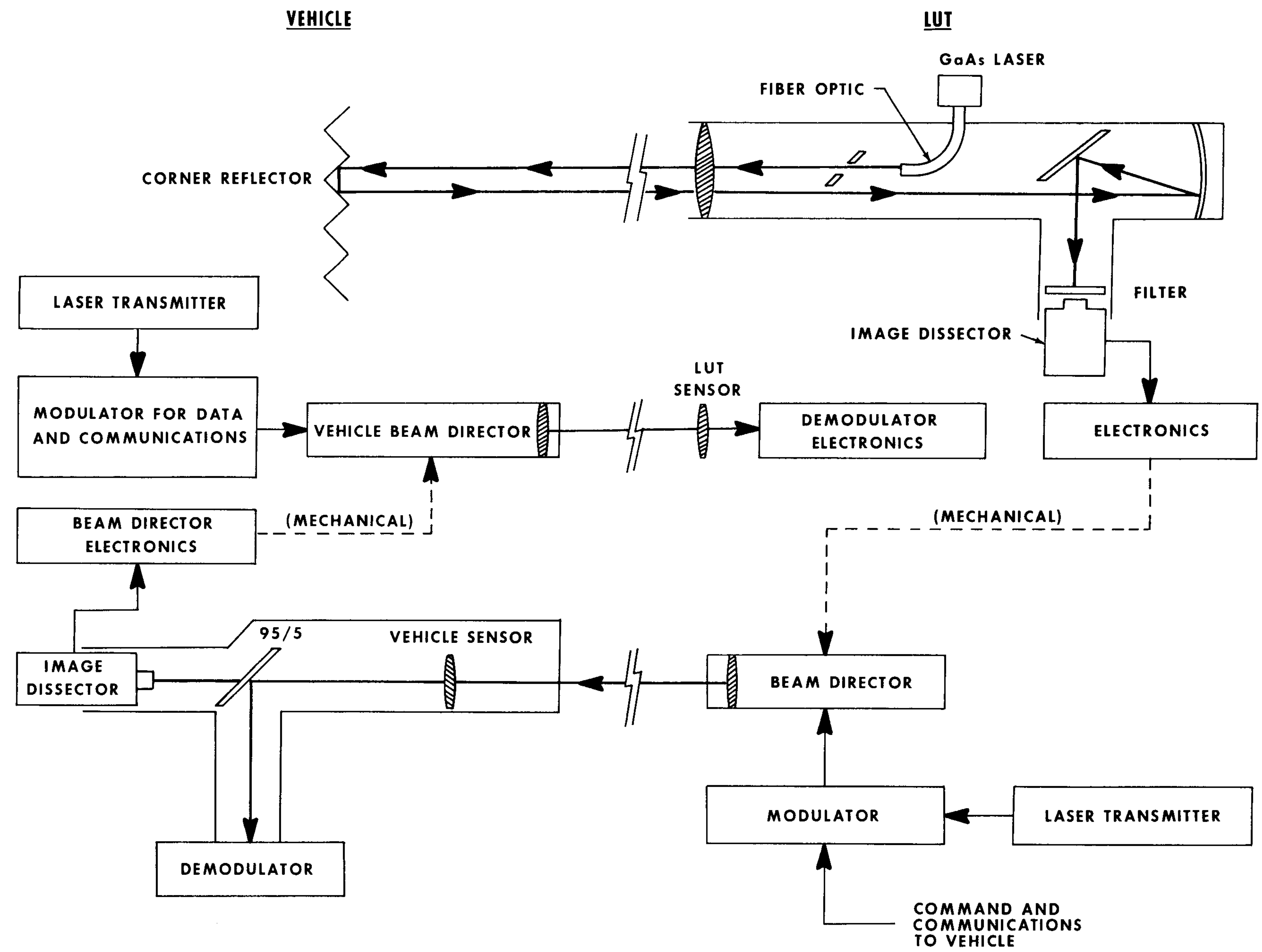


FIGURE 10. CONCEPTUAL LASER TRACKING TECHNIQUE

B. ORBITAL LAUNCH OPERATIONS

1. General:

In orbital launch operations, one of the major problems would be to establish and maintain information links between the vehicle and the checkout and launch equipment. If the necessity of using umbilicals could be reduced, several distinct advantages would be gained:

a. The need for mechanical connections and associated high vacuum problems would be reduced together with the operational aspects of how to physically perform connection and disconnection in zero "g" environment.

b. The station keeping accuracy requirement would be reduced because the vehicle would not be constrained by a limited length of cable.

c. Built-in tracking features of other concepts not only would allow accurate vehicle guidance "final setup", but could also be used for station keeping and rendezvous functions.

d. Artificial "g" technique of propellant transfer would be facilitated by not having to disconnect data link during transfer operations and then reconnect for "final setup."

e. Vehicle explosion danger to launching equipment could be reduced by increasing allowable separation distance.

The implications of advantage a. above are important enough to warrant further discussion. Advanced orbital launch operations studies have shown that a major input parameter to mission success calculations is the total number of operations that must be performed in preparing a vehicle for orbital launch. By reducing the total number of operations, such as connecting and disconnecting hardlines, the probability of mission success increases. By eliminating those operations that involve connecting and disconnecting hardlines, the probability of mission success statistically increases. The method by which the connection of the hardlines would be physically accomplished also presents a big problem. Some form of extendable mechanical droug device could be used, but the mechanical details on both ends would be very complex. The launch equipment side would require controls to swing the arm in two directions and extend and retract it. On the vehicle end would be a device to connect and disconnect the actual pin-socket connector. The mating of pin-socket connectors is an excellent opportunity to bend or break pins even under ideal conditions. The effect of high vacuum on this type of electrical connection is not known. Laboratory experiments on metal-to-metal friction and resultant gauling and near welding are not at all encouraging. If a man were used to perform this operation, not only would he be handicapped by a space suit and zero "g" environment, but would be exposed to radiation from natural sources and nuclear engines, temperature extremes, and meteorite dangers. Further, even considering perfect operation of all hardware, time is precious during advanced mission countdown operations. Launch windows will be about ten minutes for some missions. Assume the vehicle to be an adequate distance away to prevent damage to the launch equipment from engine flame impingement, nuclear engine radiation, or explosion. If one minor failure had to be corrected and reverified by the launch equipment, a launch window could be missed. This is evident because the vehicle would have to be returned to close proximity of the launch equipment and umbilical connections made. Then after the malfunction had been corrected and reverified, the connections would have to be broken and the vehicle repositioned to a safe launching distance. Missing a launch window in orbital operations is extremely costly from the aspect of the number of people involved, both in orbit and on earth, and the amount of equipment being operated. The timing aspects would be amplified by the meeting of launch windows during multiple orbital launchings.

2. Advanced data link techniques:

Based on the above discussion in paragraph 1, the techniques considered to replace umbilicals during ground operations will be reviewed for their applicability in orbital operations.

a. Radio frequency techniques: For orbital launch operations, it is found that all of the RF noise and interference problems anticipated on earth are retained. Specific problems that would be encountered in orbit if extensive RF were used would be:

(1) Increased interference from earth due to "line of sight" relationship with entire half of the earth's surface and all of its sources of spurious radio noise.

(2) Installation of special antenna "hats" to reduce interference would require exposure to space environment as much as installing umbilicals.

b. Checkout and launch equipment/vehicle systems integration: If the technique of installing checkout and launch equipment onboard the vehicle were used, the following comments would apply to orbital launch operations:

(1) The philosophy behind having equipment in orbit is to give man one more opportunity to repair or adjust the vehicle prior to the start of a long mission.

Although the length of time to inject a vehicle into orbit is short, it is the most strenuous on the vehicle equipment.

(2) Equipment installed onboard the vehicle and the selection of spares would be compromised due to static weight, volume, and power limitations.

(3) Permanent data recording would involve some form of data link regardless of where equipment was located.

Based on the above, the conclusion is made that if man is going to be used in orbit to checkout and launch a vehicle, the maximum utilization of his presence should be made. This requires sophisticated checkout and launch equipment that has not been constrained with space vehicle imposed limitations. It requires adequate spares to replace or repair equipment determined to be performing unacceptably. Most important, however, is that it requires the maximum amount of accurate and complete information about the vehicle that can be obtained by the information transmitting technique. The advantages of not burdening the vehicle with static weight of equipment and spares used only for major checkout and launch operations were stated in the Ground Launch portion of this document.

c. Optical technique: It is in space launch operations that the optical techniques of pulsed and modulated light beams display the greatest advantages over other communications techniques.

(1) Space vehicle to orbital checkout and launch equipment: Figure 11 depicts the utilization of light source and sensor matrices with a fiber optic bundle light path. Although eliminating several problems, it retains several of the disadvantages associated with umbilicals. The method of attachment to the vehicle could be an easily "space proofed" design compared to a pin-socket connector. Regardless of the simplicity, the operations of connecting and disconnecting must be performed. The constraints imposed by a finite length of fiber optic are also retained.

Figure 12 presents the concept of utilizing exactly the same laser technique in orbit that was used in figure 7 for ground launch operations. The equipment in the vehicle could be used in both ground and orbit environments. The other "end" of the link could be the same as that used on the LUT except it would be slightly modified as follows:

(a) Additional channels provided to perform docking and station keeping data transmission.

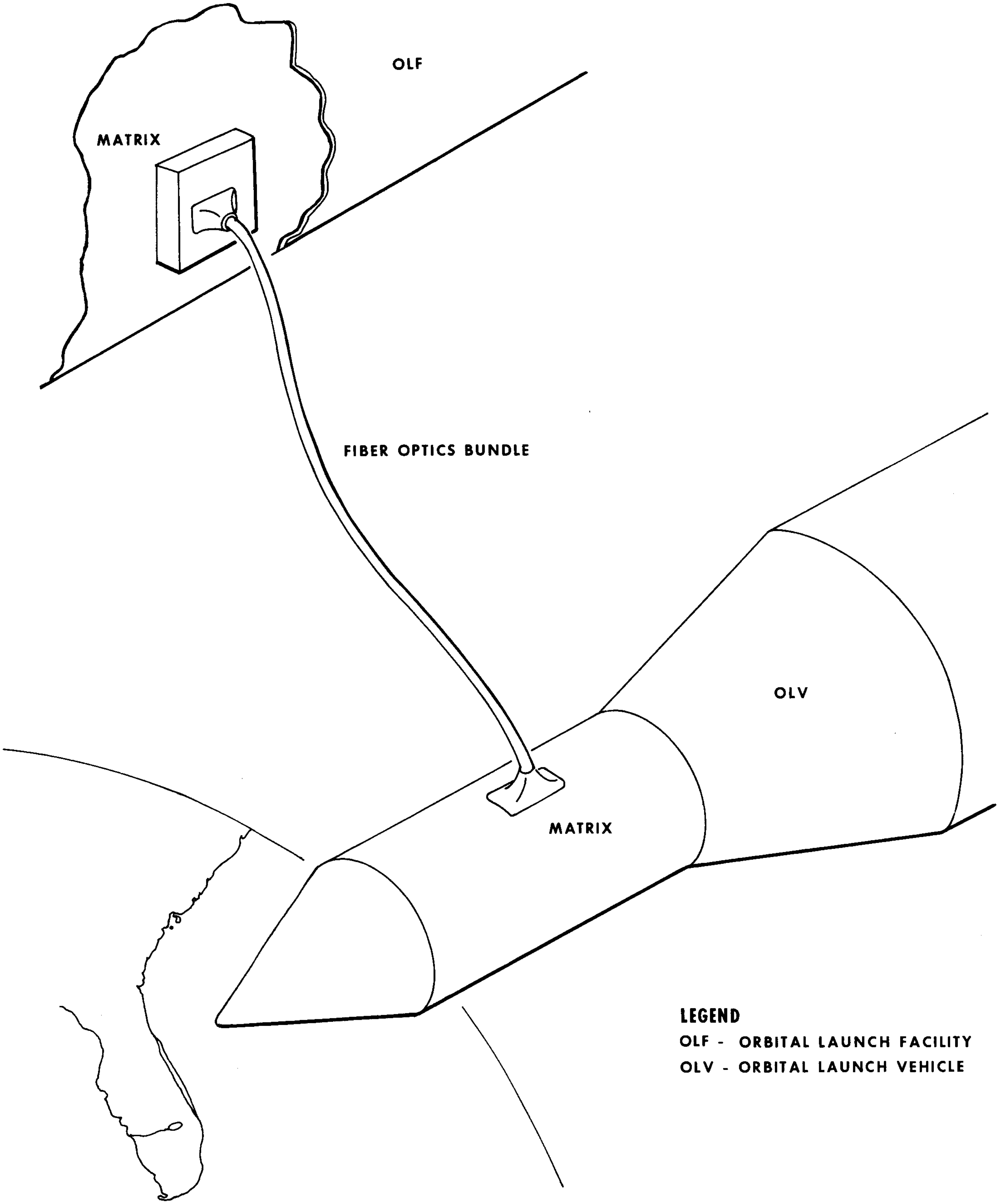


FIGURE 11. ORBITAL IMPLEMENTATION OF PULSED LIGHT

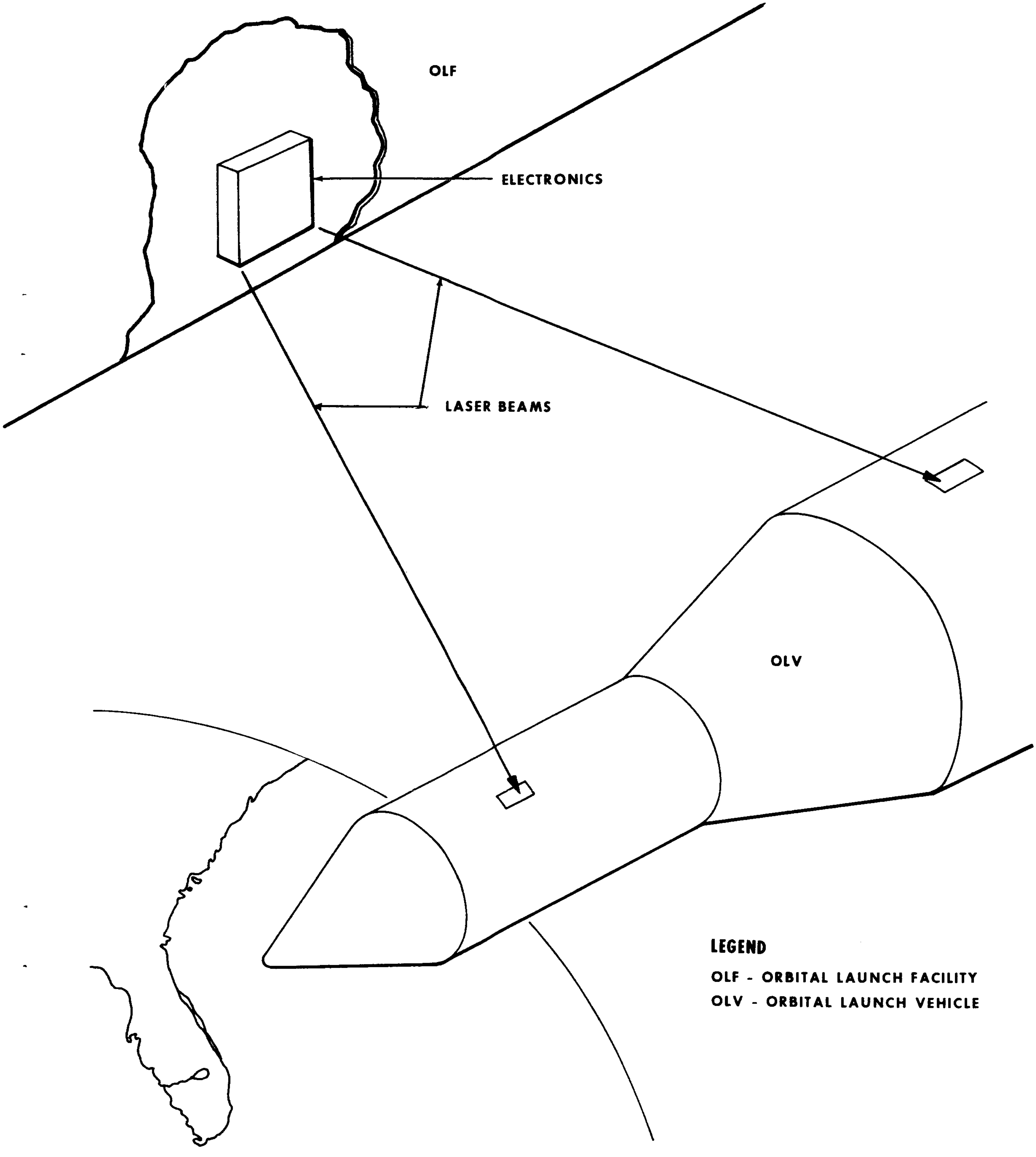


FIGURE 12. LASER LINK FOR ORBITAL CHECKOUT

(b) Broader limits of motion so the information links can be maintained during docking, station keeping, and propellant transfer operations.

(c) Range would be greater to maintain link during prelaunch period that the vehicle has drifted out to safe launching distance from the normal checkout distance. The propellant transfer operation would also require greater range capability.

(2) Other interfaces in orbital operations: Communication links with different types of vehicles, such as astro-tugs and propellant tankers, (figure 13) would utilize the same aiming and tracking technique, but the capability of associated equipment would not be as broad on either side of the interface.

(3) Orbit to earth interface: The transmission of voice and data between earth stations and orbital operations could also use the laser technique described above as in figure 14. Lasers, because of their borad frequency range, would allow a greater amount of data to be exchanged during the non-blacked out period than radio techniques. The non-interference advantages would again appear as a major improvement to the overall operation.

The previous concepts presented for orbital launch operations can be implemented using today's state-of-the-art hardware. Only development of the actual hardware in these particular configurations would be required together with some modifications to the vehicle internal power distribution wiring.

C. SUPPORTING TECHNOLOGY

Although the concepts presented in Paragraph A and B of this report could be fabricated today, there are devices in advanced development and others only in the thinking stages that will materially contribute to the future usage of these concepts.

1. Microcircuits:

Microcircuits are those devices of integrated circuit or thin film technology. They are charcterized by their small size, low power drain, and high reliability. There are many different circuits available now of both integrated and thin film form.

New circuits are being fabricated by these techniques and are being offered to the market at a high rate. Extensive literature is available on microcircuitry techniques; therefore, it will only be noted that this technology, although advanced, is available for many applications, such as those presented.

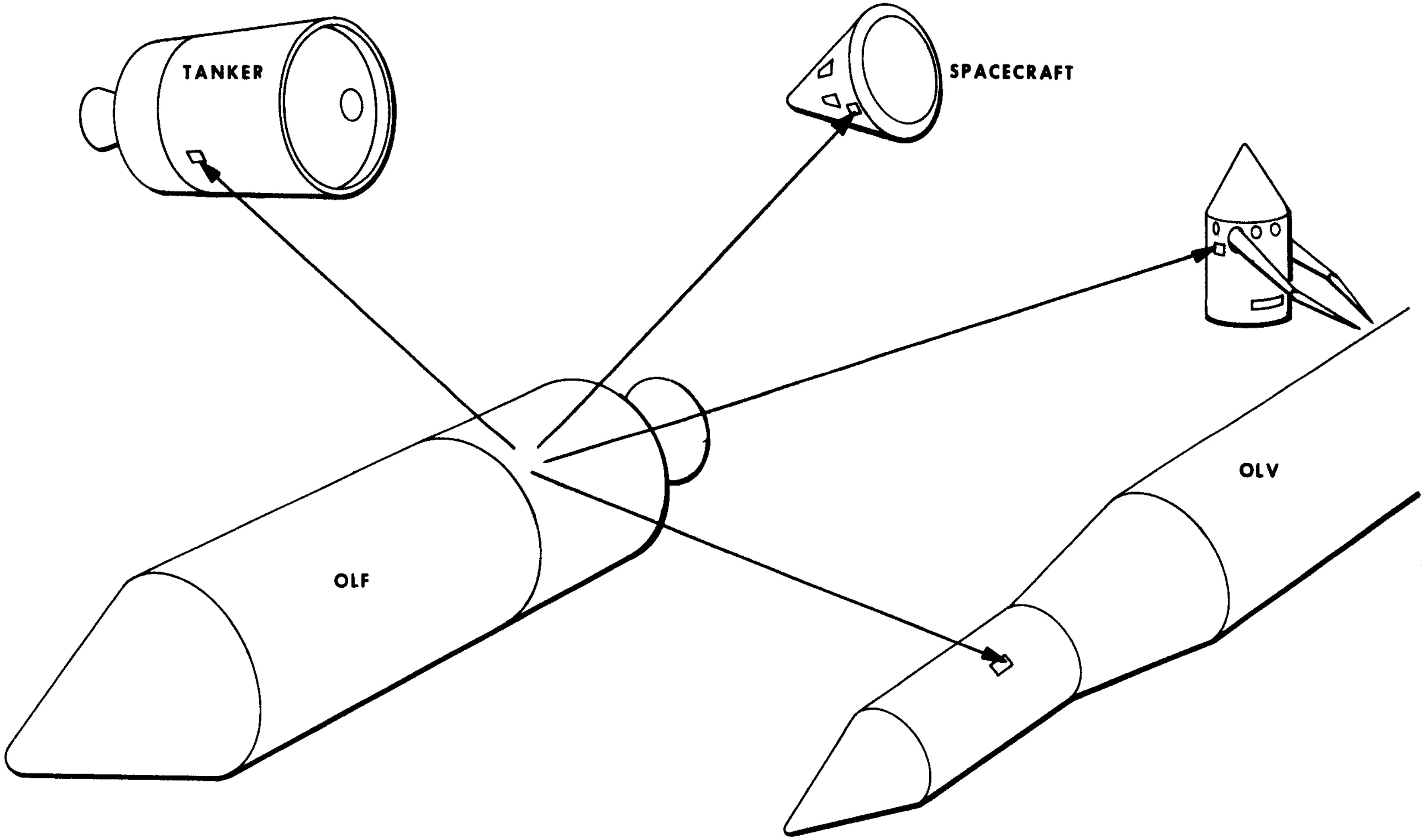


FIGURE 13. LASER LINKS WITH ORBITAL SUPPORT EQUIPMENT

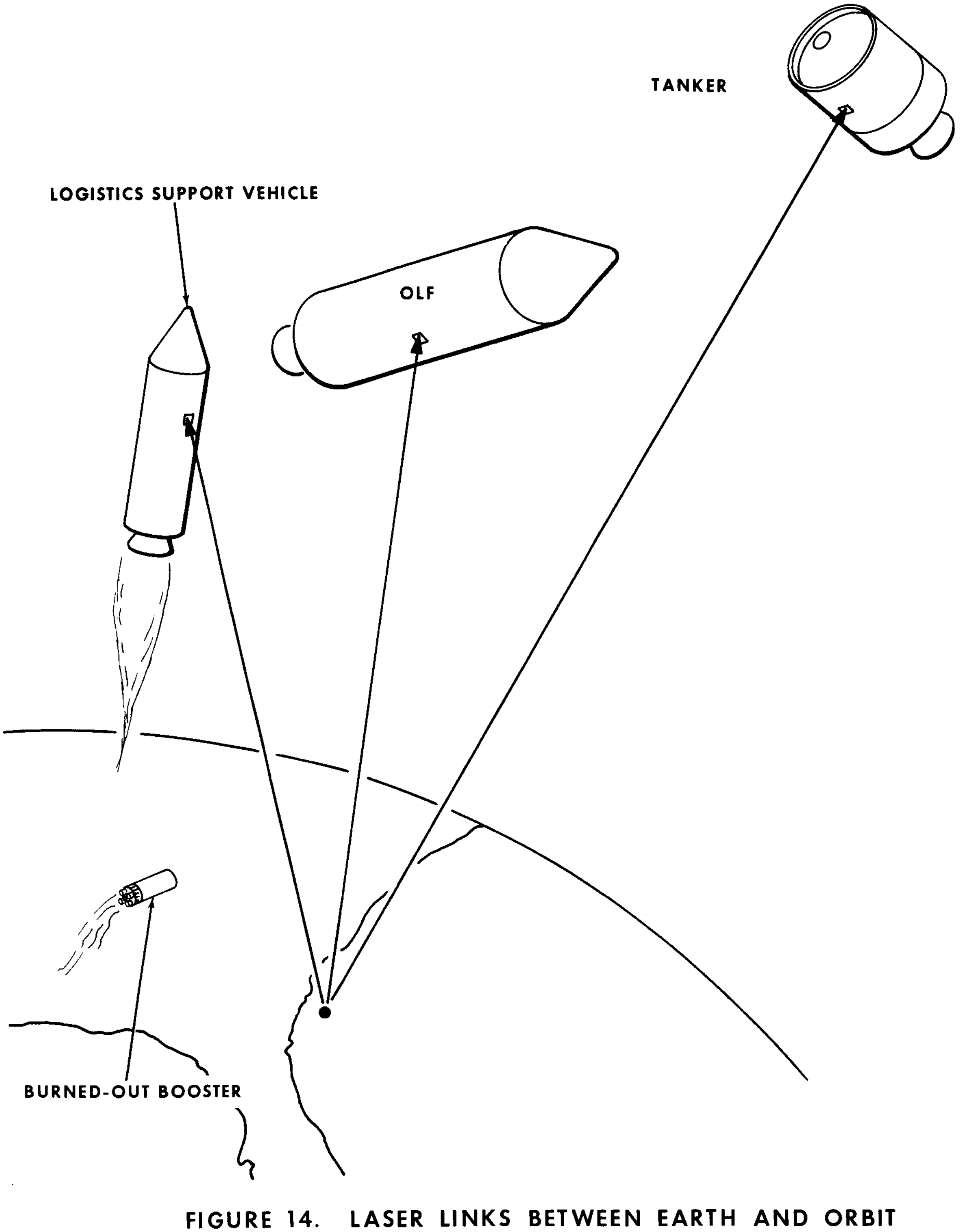


FIGURE 14. LASER LINKS BETWEEN EARTH AND ORBIT

2. Functional devices:

One of the areas which is not developed enough for present or even immediate future use is that of functional devices. This area considers devices and techniques which are very little beyond the thinking stage but would directly contribute to the conceptual systems previously described.

In broad terms, a functional device is one that performs a complete circuit or even system function.

From the latest examples of microminiaturized integrated circuits, a specific circuit will be chosen to illustrate what area functional devices are attempting to improve. A Texas Instrument SN511 R/S FLIP-FLOP[1] network is chosen having the following dimensions:

Case:	.250 x .125 x .035 inches
Microcircuit Chip:	.195 x .070 x .008 inches
Leads:	.004 inch diameter x .083 inches long
Case volume =	.001094 $inches^3$
Chip volume =	.000108 $inches^3$

The volume of the chip is only one-tenth the volume of the total case (1/10.02). If we now consider the actual usage of the device in which it is mounted to a printed circuit board and the leads connected to the printed wiring, the total volume occupied by the case, figure 15, will apply. The total volume enclosing one microcircuit device is .00352 in^3 or a ratio of 1:30.3. The need to protect the chip from normal environment is quite acceptable, but the need for functional devices is seen in the 1:20 ratio difference for lead volume and heat dissipation requirements. The main objective in functional devices programs is to reduce the size and weight of lead requirements.

The ultimate would be a reduction to only two leads. The simplification process involves forgetting about simulating circuits and concentrating on elements which are designed directly from physics without regard to previous circuits. An example of a functional circuit is the prezoelectric crystal. This crystal has a combination of capacitance and inductance for an equivalent circuit but is a solid and has

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[1] A SOLID CIRCUIT [R] semiconductor flip-flop/counter with emitter-follower outputs. Case is a hermetically sealed package with 10 lateral leads.

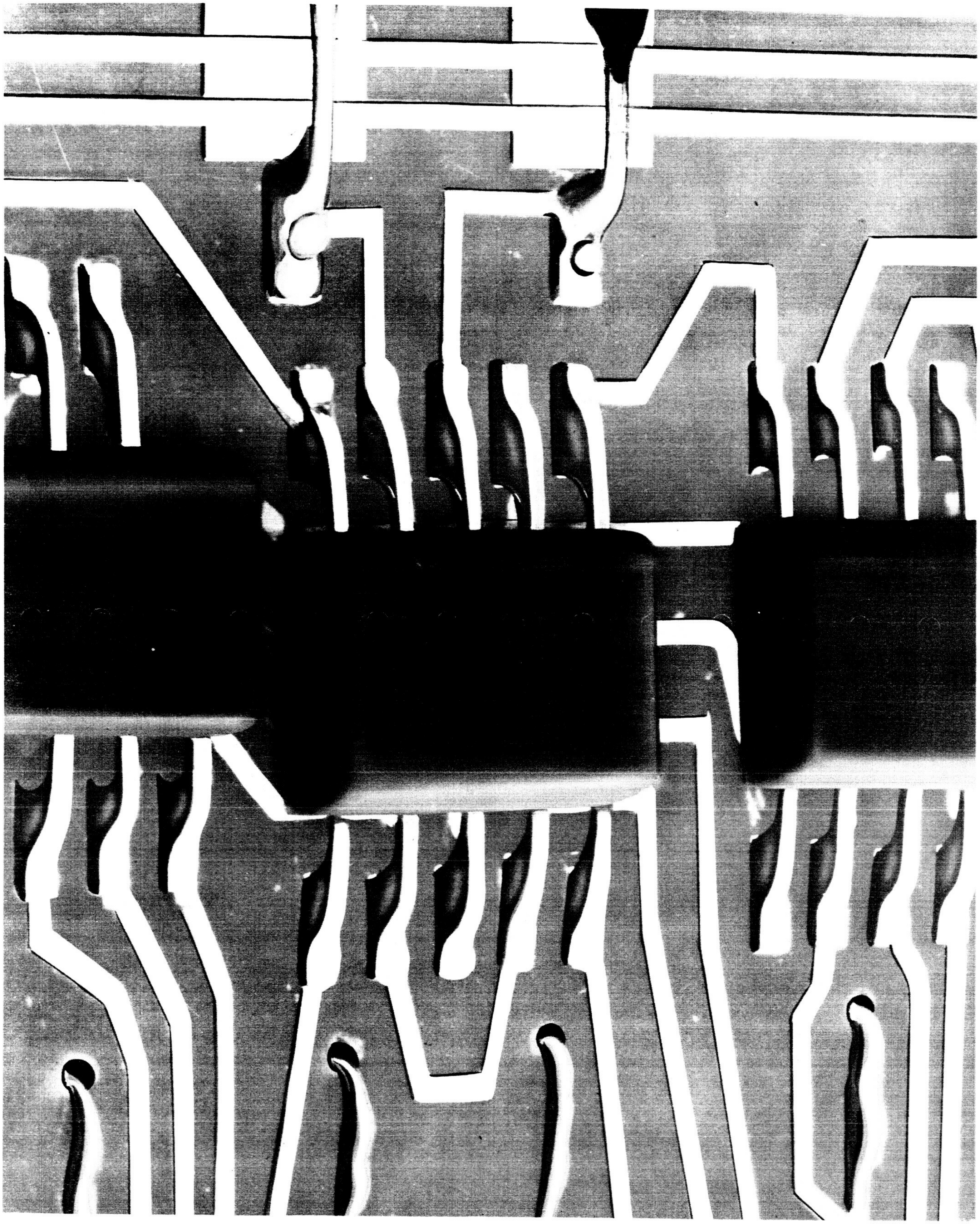

FIGURE 15. TYPICAL MOUNTING OF MICRO CIRCUIT

higher "Q" values than can be achieved with actual components (tuned circuits). A form of functional device already in use that further illustrates this type of thinking is the PNPN diode shown in figure 16. Two transistors, a diode, and resistor are replaced by a single device. Expanding on the PNPN principle and combining units on a single substrate, a replacement for a semi-conductor stepping switch can be made as shown in figure 17. As this thinking develops into hardware, this technique will be replacing integrated circuits as they replaced transistors. Further increases in payload capacity or increases in functional performance will result.

3. Mössbauer effect devices:

Another device which could be used very well for position tracking and guidance setup utilizes a Mössbauer effect device. This device operates on much the same principle as a laser except instead of a light beam output, it has an output of gamma radiation. Some development work has been done, but hardware is not as far along for this device as for lasers. Theoretically, these devices should be able to measure velocities with an accuracy of $\pm$ .01 CM/Sec ($\pm$ 0.0039 inches/sec) at a range of 500 feet. Although this magnitude of accuracy is not necessary for ground tracking of a swaying vehicle, it would be an excellent device to use in many areas of orbital operations. Some of these areas would be:

a. Aiming and tracking of laser information links.

b. Accurate docking and station keeping operations.

c. Accurate guidance alignment and checkout immediately prior to launch. During guidance setup, any minute rotational rate could be determined and removed as final "initial position" data are transmitted to the vehicle.

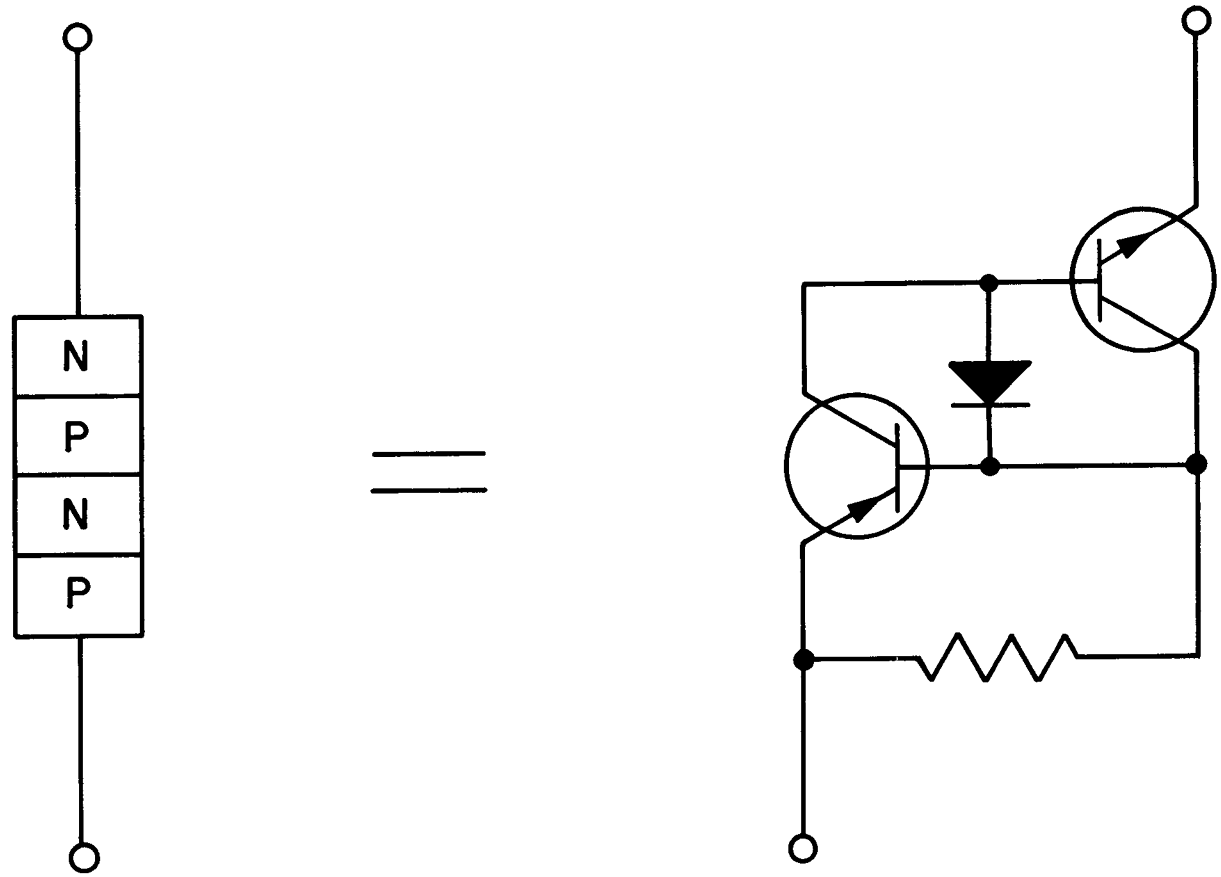

FIGURE 16. PNPN DIODE AND ELECTRONIC EQUIVALENT

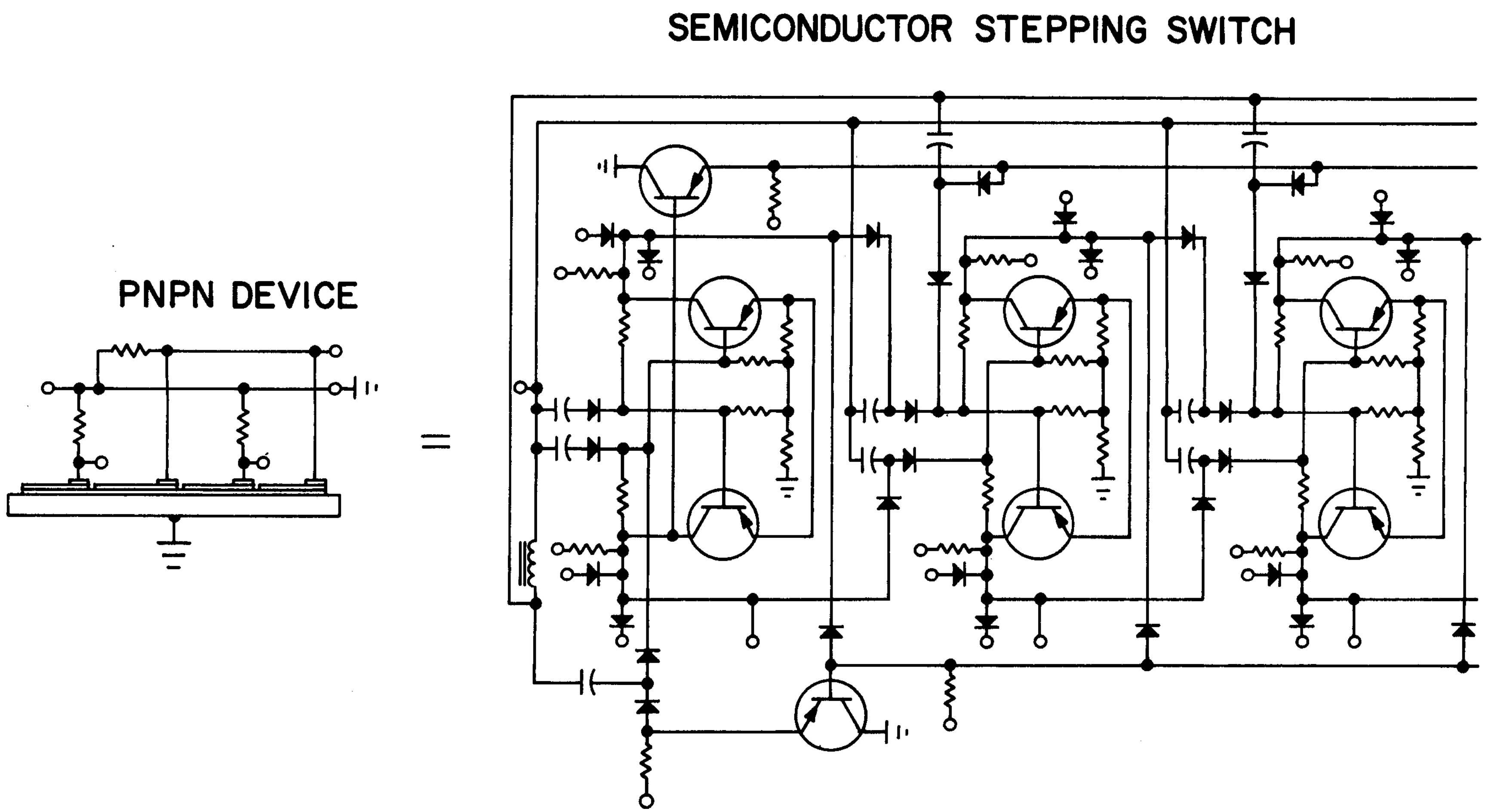

FIGURE 17. PNPN DEVICE COMPARED TO CONVENTIONAL CIRCUIT

SECTION III

CONCLUSIONS AND RECOMMENDATIONS

A. CONCLUSIONS

After analyzing other techniques that could be used in place of umbilical cables, it is concluded that the advantages of the optical methods are far superior to all others considered.

The state-of-the-art in optical devices has been investigated and found capable of accommodating all concepts presented. This does not mean, however, that development effort would not be required to implement the usage of optics. This development would include integration of the concepts into the total vehicle systems.

New electronic devices are presently being developed in laboratories which will add to the advantages already achievable with "off-the-shelf" hardware.

B. RECOMMENDATIONS

It is strongly recommended that steps be taken to initiate one or more of the following activities:

1. Stimulate industry along the lines of developing prototype hardware for actual representative data transmission by one of the optic techniques presented.

2. Provide support to those companies who already have hardware demonstrations. An existing demonstration device could economically be modified to develop techniques.

3. Provide support to industry for the fabrication of a specific prototype communication demonstration with capability adequate for back-up use during an actual launch.

It is not recommended that any further detailed study work be done other than normal developmental groundwork.

APPENDIX A

Comparison of three techniques for reducing umbilical connections to a space vehicle:

ITEM OR PROBLEM AREA CONSIDERED	TECHNIQUE CONSIDERED		
	RADIO FREQUENCY	TEST EQUIP/VEHICLE INTEGRATION	ELECTRO-OPTICAL
Vehicle Power	1. Functional power increased 2. Transmitting power increased from 80 watts for 3500 channels	1. Functional power increased 2. Transmitting power decreased 3. Computing power required	1. Functional power increased 2. Transmitting power reduced to $3x10^{-5}$ watts for 5,000 channels
Vehicle Cooling	Increased due to higher power required	Increased due to higher power required	Increased due to functional power; reduced due to transmitting power reduction
Vehicle Weight	Increased due to additional transmitting and control equipment, higher power and more cooling	Increased due to additional equipment, power, cooling and wiring. Reduced due to less transmitting requirements	Increased due to additional wiring and equipment with functional power. Reduced due to more efficient transmitting technique.
Vehicle Volume Required	Increased due to added equipment	Increased due to added equipment. Reduced due to removal of some transmitting boxes	Increased due to additional wiring. Reduced due to removal of most transmitting equipment.
Vehicle Complexity	Increased	Greatly increased due to internal operations req'd	Increased

ITEM OR PROBLEM AREA CONSIDERED	TECHNIQUE CONSIDERED		
	RADIO FREQUENCY	TEST EQUIP/VEHICLE INTEGRATION	ELECTRO-OPTICAL
Checkout and Launch Capability	Same	Reduced due to flight equipment constraints	Increased due to more channels being easily available
Fault Isolation Using Ground Equipment	Same	Reduced due to limited use of data transmission	Increased due to more channels being available
Radio Frequency Interference	Increased	Reduced	Eliminated
Modification to Vehicle Difficulty	Same or more complex	Increased due to changing two sets of equipment, both inside the vehicle structure	Same or more complex
Electrical Power Hydraulic and Pneumatic Connections Required	Yes, this theme is for data, low power control and voice	Yes	Yes, but electrical power transmission is being studied.
Transmission of Power	No	Not applicable	Possible in future
Special Connections Required	Special interference devices required for abating spurious radiation	No	Depends on particular concept used such as fiber optics attachment
Hardware Available	Yes	Yes	Yes
Ground Equipment Complexity	Increased	Reduced	Increased
Permanent Data Recording Capacity	Same	Reduced due to Limited transmission being made	Same or greater if available channel capacity were utilized

ITEM OR PROBLEM AREA CONSIDERED	TECHNIQUE CONSIDERED		
	RADIO FREQUENCY	TEST EQUIP/VEHICLE INTEGRATION	ELECTRO-OPTICAL
Multiple Launch Operations Affected	Yes, due to increased interference	No, unless reduced fault isolation "power" is considered	No
Accidental Pyrotechnics Possible	Yes	Yes, but less than RF technique	No
Operations Time For Setup and Start of Launch procedures	Reduced because of less umbilicals to connect	Reduced	Reduced
Transmission Affected By Other Environment	Yes, by other RF signals and ionized exhause plume during ascent	No, due to limited transmission being made	Yes, line of sight must be maintained but not affected by exhaust plume

REFERENCES

1. Aviation Week and Space Technology, May 18, 1964, page 100.

APPROVAL

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AN INTRODUCTION TO

ADVANCED CONCEPTS IN LAUNCH OPERATIONS

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